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13. ABSTRACT *(Maximum 200 words)*

This research program seeks to understand and control atomic collisions at ultracold temperatures where quantum and light-filed effects lead to new interactions between atoms. We have pursued experimental and theoretical investigations of optical shielding and suppression, and the nature of ground-state collisions in and near a Bose-Einstein condensate. This research shows how inelastic collisions can be turned on and turned off by light fields, how the scattering length of ultracold ground-state collisions might be altered by light fields.

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Experiments and Theory in Ultracold Collision Dynamics

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October 6, 1997

U. S. Army Research Office

DAAH04-94-G-0028

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Final Progress Report on Research Agreement DAAH04-94-G-0028

1. Statement of the Problem Studied—The problem is to understand and control atomic collisions at ultracold temperatures where quantum and light-field effects lead to new, sometimes collective, interaction between atoms. These interactions may lead to the development of new phases of condensed matter including the possibility of atom lasers.
2. Summary of the Most Important Results-- We have pursued experimental and theoretical investigation of optical shielding and suppression in ultracold collisions. A remarkable feature of the ultracold environment is the ability to optically reroute entrance-channel scattering flux and thereby control the exit channel of the collisional encounter.. In the 1996 interim progress report we cited our Physical Review Letter, "Optical Suppression of Photoassociation Ionization in a Magneto-Optical Trap (Phys. Rev. Lett. **73**, 1911 (1994), which described the first observation of optical suppression of a bond-forming, associative collision. In 1995 we continued to explore the nature of this suppression effect. We have shown that a suppressor optical field, tuned to the blue of the atomic resonance line, at relatively high intensities (a few Watts per square centimeter) can suppress the reactive channel by over a factor of twenty (Phys. Rev. A **52** R913 (1995)). We have also shown, however, that the suppression phenomenon is not as effective as predicted by a simple two-state Landau-Zener model, and we have developed a rigorous (although spinless) theory that takes into account multiple-photon transitions during the course of the collision. The article is entitled "Theory of Optical Suppression of Ultracold Collision Rates by Polarized Light" with R. Napolitano and P. S. Julienne as co-authors (Phys. Rev. A **55**, 1191 (1997). Another consequence of this high-intensity suppression is the theoretical prediction of a very pronounced polarization effect. We carried out experiments to confirm this prediction and indeed did show (Phys. Rev. Lett.**76**, 2033 (1996)) that this polarization effect is present and very strong. In order to follow up the discovery of the polarization effects we have carried out cold collisions in a highly collimated atomic beam. The results show agreement with the prediction that linearly polarized light is a less effective suppressor than predicted by a one-dimensional Landau-Zener model and that suppressor light polarized perpendicular to the collision axis is more effective than light polarized parallel to the axis. These findings are in qualitative agreement with the quantum closed-coupled theory of Napolitano, et al. We have also carried out photoassociative ionization experiments in ultracold Rb collisions. We have reported the observation of direct, two-color photoassociative ionization collisions between ^{85}Rb atoms cooled and confined in a magneto-optical trap(Phys. Rev. A **52**, R4332 (1995)). We also measured the resulting Rb_2^+ ion spectra and compared it to earlier trap-loss fluorescence spectra.
3. List of Publications and Technical Reports

A. Phys. Rev. A **52**, R913 (1995) "Intensity Dependence of Optical Suppression in Photoassociative Ionization Collisions in a Sodium Magneto-optic Trap" (L. Marcassa, R Horowicz, S. Zilio, V. Bagnato)

B. Phys. Rev. Lett. **76**, 2033 (1996) "Polarization Dependence of Optical Suppression in Photoassociative Ionization Collisions in a Sodium Magneto-optic Trap", (V. Bagnato, R. Horowicz, L. Marcassa, S. Muniz, S. Zilio, R. Napolitano, and P. S. Julienne)

C. Phys. Rev. A **55**, 1191 (1997) "Theory of Optical Shielding of Ultracold Collisions by Polarized Light", (R. Napolitano, and P. S. Julienne)

D. Appl. Phys. **80**, 8 (1996) "Optical Collimation and Compression of a Thermal Atomic Beam" (C.-C. Tsao, Y. Wang, and V. S. Bagnato)

E. Phys. Rev. A **52**, R4332 (1995) "Stimulated Two-Color Photoassociative Ionization in a Rubidium Magneto-optic Trap" (D. Leonhardt)

F. Phys. Rev. Lett. **78**, 1880 (1997) "Collisional Stability of Double Bose Condensates," (P. S. Julienne, F. H. Mies, E. Tiesinga, and C. J. Williams)

G. Phys. Rev. A **56**, 1486 (1997) "Prospects for influencing scattering lengths with far-off-resonant light," (J. Boh and P. S. Julienne)

4. Scientific Personnel

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